

Single spin asymmetry in DVCS

Andreas Freund^a, Mark Strikman^b

^a *I.N.F.N, Sezione Firenze, Lg. Enrico Fermi 2, 50125 Florence, Italy*

^b *The Pennsylvania State University, University Park, Pa 16802, USA and DESY-Hamburg, Germany*

Abstract

In the following note, we will present an estimation of the single spin asymmetry in deeply virtual Compton scattering (DVCS) which directly allows one to test predictions of the ratio of the imaginary part of the amplitude in DIS to DVCS, as well as access the skewed parton distributions at small x in the DGLAP region. We find it to be large for the HERA kinematics to be accessible in forthcoming runs with polarized electrons.

PACS: 12.38.Bx, 13.85.Fb, 13.85.Ni

Keywords: Evolution, Parton Distributions, Deeply Virtual Compton Scattering

I. INTRODUCTION

The single spin asymmetry (SSA) in deeply virtual Compton scattering (DVCS) which was first discussed in Ref. [1] and subsequently in [2,3], is directly proportional to the interference term between the DVCS and the Bethe-Heitler (BH) process and thus offers a direct way of accessing the imaginary part of the DVCS amplitude [1–3] in the scattering of polarized electrons off unpolarized protons. Such measurements would be feasible at HERA in the near future (around the end of 2000) when the spin rotators will be installed both at the ZEUS and H1 experiment. This then allows a direct check of our prediction [4] obtained in the $\alpha_s \ln Q^2$ approximation of a large (a factor ~ 2) enhancement of the imaginary part of the DVCS amplitude for small x kinematics as compared to the the imaginary part of the DIS amplitude as measured through $F_2(x, Q^2)$. Furthermore, this asymmetry is another physical observable, besides the azimuthal angle asymmetry A proposed in [4], which allows one to directly access and extract the skewed parton distributions (SPD's) [6], at least in the DGLAP region [7]. This note is structured in the following way: In the next section we will give the definition of the SSA along with an analytical expression to $\alpha_s \ln Q^2$ accuracy and in Sec. III we will give numbers for this asymmetry in the HERA kinematical regime, followed by conclusions.

II. THE SINGLE SPIN ASYMMETRY

In order to form the SSA in DVCS one scatters polarized electrons/positrons off an unpolarized proton target and then takes the difference in differential cross sections between

positive and negative helicity initial states. The exact definition is

$$A_s = \frac{\int_0^\pi d\phi (d\sigma_+ - d\sigma_-)_{DVCS+BH} - \int_\pi^{2\pi} d\phi (d\sigma_+ - d\sigma_-)_{DVCS+BH}}{\int_0^{2\pi} d\phi (d\sigma_+ + d\sigma_-)_{DVCS+BH}} \quad (1)$$

where $+$, $-$ refers to the helicity state, ϕ is the azimuthal angle in the transverse scattering plane as defined in [4] and $DVCS+BH$ means that we are considering the total differential cross section of these two processes. Note that $d\sigma_{DVCS+BH,unpol.} = \frac{1}{2}(d\sigma_+ + d\sigma_-)$. There is another way of writing the SSA as well as A by weighting the respective interference term by $\sin(\phi)$ in the case of SSA and $\cos(\phi)$ in the case of A , as originally proposed by the authors of [3], so one obtains in the SSA case

$$A_s = \frac{\int_0^{2\pi} d\phi \sin(\phi)(d\sigma_+ - d\sigma_-)_{DVCS+BH}}{\int_0^{2\pi} d\phi (d\sigma_+ + d\sigma_-)_{DVCS+BH}}. \quad (2)$$

The difference between this and our definition is a factor of $\frac{\pi}{4}$ by which the asymmetry from Eq. (2) would be smaller than the one from Eq. (1). The advantage of the second definition might be that one does not need to know whether the final state electron and photon are in the same or opposite detector hemispheres, one just has to integrate all the data by the respective weight function.

In the center of mass frame of the final state photon and proton, we find the following expression for $d\sigma_{int} = d\sigma_+ - d\sigma_-$ following our methods from [4] for small x, t and $Q^2 \gg -t$ and the results for the unpolarized hadronic and spin-dependent leptonic tensor for the interference part in the form given in [2]:

$$\frac{d\sigma_{int}}{dx dy d|t| d\phi} = \frac{2\alpha^3 s_{ep} F_2(x, Q^2) F_1(|t|) e^{-B|t|/2} \sin(\phi) y}{\sqrt{|t|} Q^5 R \sqrt{1-y}} \left(1 - (1-y)^2 + \frac{2\sqrt{|t|} \cos(\phi)}{Q} \frac{1 - (1-y)^3}{\sqrt{1-y}} \right) \quad (3)$$

where R is the ratio of the imaginary part of the DIS to the imaginary part of the DVCS amplitude which was taken from [4], x, y, t and Q^2 are the usual kinematical invariants, ϕ is the azimuthal angle of the leptonic and hadronic scattering plane [4] specifying the off-planarity of the event, s_{ep} is the center of mass energy of the electron-proton system, $F_2(x, Q^2)$ the normal structure function [5], B is the slope of the t -dependence of the DVCS amplitude which we took to be an exponential at small t and

$$F_1(|t|) = \frac{G_E(|t|) + \frac{|t|}{4M^2} G_M(|t|)}{1 + \frac{|t|}{4M^2}} \quad (4)$$

the t -dependence of the BH contribution appearing in the interference term [4], where we use the regular dipole fit for the electric and magnetic nucleon form factors. Note that the term $\sin(\phi)\cos(\phi)$ in Eq. (3) integrates to zero in the definition of A_s . Eq. (3) is in agreement with Ref. [2], where however the DVCS amplitude was not computed. For the total, unpolarized, differential cross section in the denominator of A_s we use our results from [4]

$$\begin{aligned}
\frac{d\sigma_{DVCS+BH,unpol.}}{dx dy d|t| d\phi} = & \frac{\pi\alpha^3 s}{4R^2 Q^6} (1 + (1-y)^2) e^{-B|t|} F_2^2(x, Q^2) (1 + \eta^2) \\
& + \frac{\alpha^3 s y^2 (1 + (1-y)^2)}{\pi Q^4 |t| (1-y)} \left[\frac{G_E^2(t) + \tau G_M^2(t)}{1 + \tau} \right] \\
& + \frac{\eta\alpha^3 s y (1 + (1-y)^2) \cos(\phi) e^{-B|t|/2} F_2(x, Q^2)}{2Q^5 \sqrt{(|t|)} \sqrt{(1-y)} R} \left[\frac{G_E(t) + \tau G_M(t)}{1 + \tau} \right] \quad (5)
\end{aligned}$$

where the first term corresponds to the DVCS differential cross section, the second to the BH differential cross section and the third term is the interference contribution of DVCS and BH to the total differential cross section and η is the ratio of real to imaginary part of the DIS amplitude [4]. Note that after the ϕ integration as required in the denominator of Eq. (1), the interference term drops out and one is only left with the DVCS and BH contributions respectively.

III. NUMBERS FOR THE SINGLE SPIN ASYMMETRY

At $Q^2 = 3.5 \text{ GeV}^2$ with a B of 8 GeV^{-2} , we find the asymmetry A_s from Eq. (1) to be maximal around 32% at $y = 0.5$ and $-t = 0.2 \text{ GeV}^2$ for $x = 10^{-4}$ and about 27% for $x = 10^{-3}$.

At $Q^2 = 12 \text{ GeV}^2$ with a B of 5 GeV^{-2} , we find the asymmetry A_s from Eq. (1) to be maximal around 31% at $y = 0.5$ and $-t = 0.35 \text{ GeV}^2$ for $x = 10^{-4}$ and about 28% for $x = 10^{-3}$ and about 12% at $x = 10^{-2}$. For more details see Figs. 1 and 2.

This very large asymmetry, in comparison with the azimuthal angle asymmetry A from [4], is mainly due to the fact that first, we are dealing with the imaginary part of the DVCS amplitude which is about a factor 3 to 4 larger than the real part and secondly one should note that, despite the almost identical structure of terms in A_s and A , there is an extra factor of 2 in A_s as compared to A . To counter these huge enhancement factors there is only the altered y dependence, albeit quite strongly altered, which pushes the maximum of A_s to larger y values than in the case of A and forces A_s only to be about a factor 2 to 3 larger than A .

Experimentally, such a huge asymmetry should be fairly easily measurable at HERA, which as mentioned in Sec. I, would give one an interesting opportunity to compare the imaginary parts of the DIS and DVCS amplitudes as well as being able to extract the skewed gluon distribution at small x albeit only in the DGLAP region.

In this note we have shown that the single spin asymmetry in DVCS should be very sizable in the HERA regime of moderately large Q^2 , small x and small t and thus fairly easily measurable at HERA. This opens new avenues of comparing hadronic amplitudes as well as extracting the skewed gluon distribution at small x in the DGLAP region.

ACKNOWLEDGEMENTS

A.F was supported by the E. U. contract #FMRX-CT98-0194 and M.S was supported in part by the U.S. Department of Energy.

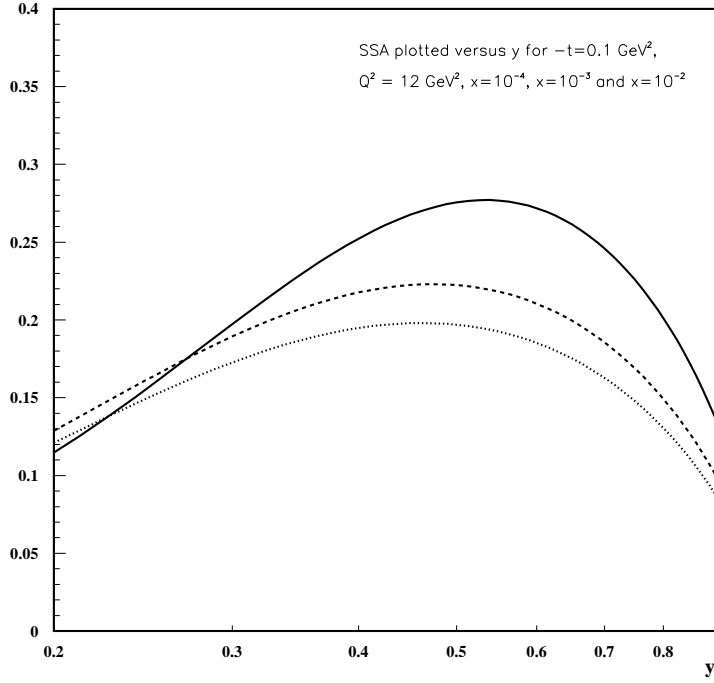
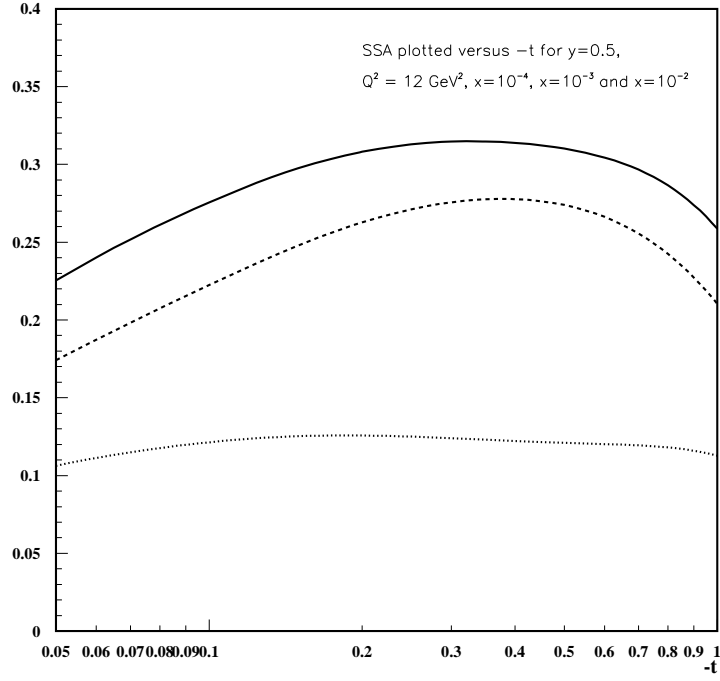


FIG. 1. a) The SSA is plotted versus $-t$ for $x = 10^{-4}$ (solid curve), $x = 10^{-2}$ (dotted curve) and $x = 10^{-3}$ (dashed curve) for $Q^2 = 12 \text{ GeV}^2$, $B = 5 \text{ GeV}^{-2}$ and $y = 0.5$. b) The SSA is plotted versus y for the same x, Q^2, B and $-t = 0.1 \text{ GeV}^2$.

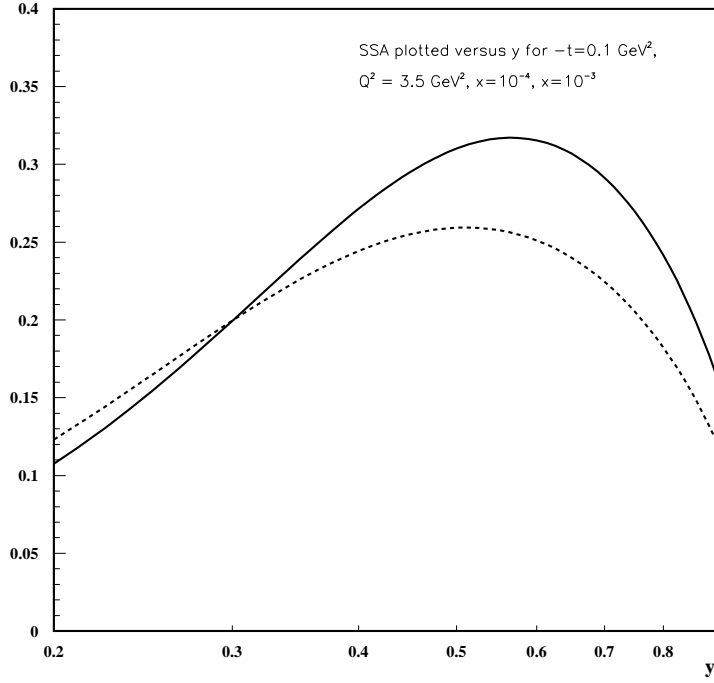
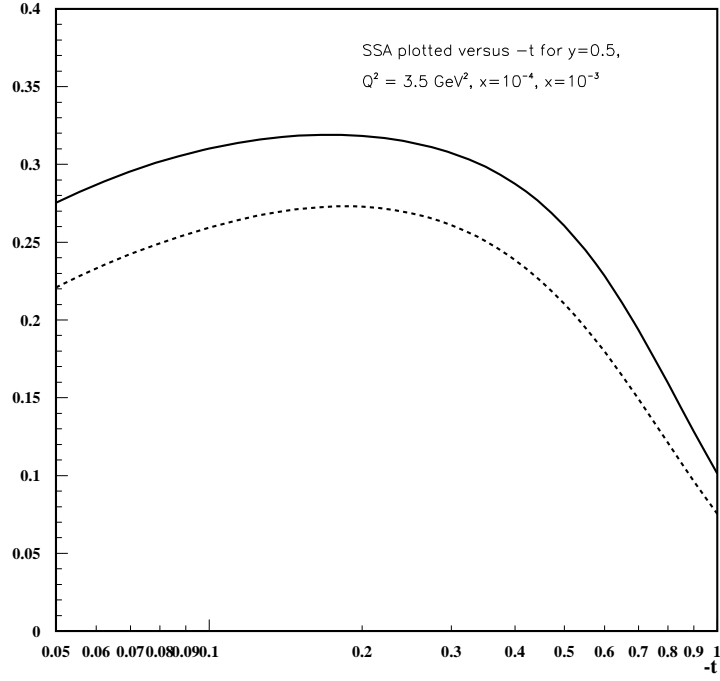


FIG. 2. a) The SSA is plotted versus $-t$ for $x = 10^{-4}$ (solid curve), and $x = 10^{-3}$ (dashed curve) for $Q^2 = 3.5 \text{ GeV}^2$, $B = 8 \text{ GeV}^{-2}$ and $y = 0.5$. b) The SSA is plotted versus y for the same x, Q^2, B and $-t = 0.1 \text{ GeV}^2$.

REFERENCES

- [1] P. Kroll, M. Schürmann, P.A.M. Guichon, Nucl. Phys. **A598** 435 (1996).
- [2] X.-D. Ji, Phys. Rev. **D55** (1997) 7114.
- [3] M. Diehl et al. , Phys. Lett. **B411**, 193 (1997)
- [4] L. Frankfurt, A. Freund and M. Strikman, Phys. Rev. **D58** (1998) 114001 (hep-ph/9710356) Erratum Phys. Rev. **D59** (1999) 11990 and hep-ph/9806535 submitted to Phys. Lett. B.
- [5] The F_2 data for the estimation of A_s was taken from Nucl. Phys. **B470** (1996) 3.
- [6] A. Freund, hep-ph/9903488, submitted to Phys. Lett. B.
- [7] Note that the imaginary part of the DVCS amplitude is only sensitive to the SPD's in the DGLAP region, see for example [2–4,6].